A Textile Antenna for Protective Clothing

C. Hertleer, H. Rogier. *Senior Member, IEEE*, and L. Van Langenhove,

***Abstract*—This paper presents a textile antenna designed to be integrated into protective clothing since it is made out of a high performance aramid fabric. A microstrip patch antenna is designed for operating in the 2.45 GHz Industrial, Scientific and Medical (ISM) band for short range communication to transmit the wearer's life signs to a nearby base station. In order to enhance flexibility and thus comfort for the wearer, electrotextiles are used for antenna patch and ground plane. When integrated into the garment, the antenna requires a finite ground plane and operates in the presence of the body, hence changing its characteristics. Furthermore, when a textile antenna is integrated into a garment the patch might bend. Therefore, a rectangular-ring topology is proposed to preserve the antenna characteristics in real-life applications. This research will therefore contribute to a new generation of protective clothing with extensive functionalities.**

I. Introduction

THE development of *wearable intelligent textile systems* has altered the concept of clothing. New generation garments are capable of monitoring the wearer's vital signs and activity as well as environmental parameters [2], [3]. Because this is done in a –for the wearer- unobtrusive and comfortable way, these garments are quite exceptional. Additionally, the introduction of intelligent textiles has uncovered the need for wireless communication systems that are unnoticeably integratable into clothing [1], [4]. The European Integrated Project Proetex (FP-2004-IST-4-026987) carries out research for the development of wearable textile systems to support the work of emergency rescuers and firemen, next to a victim's patch [6]. Data concerning the operator's health status and surrounding environmental risks can be communicated to a nearby base station. Therefore, an off-body wireless link is established where the antenna on the operator's side is a textile antenna to be integrated into the garment. The presented work reveals the design methodology and the measured results of an aramid based textile antenna.

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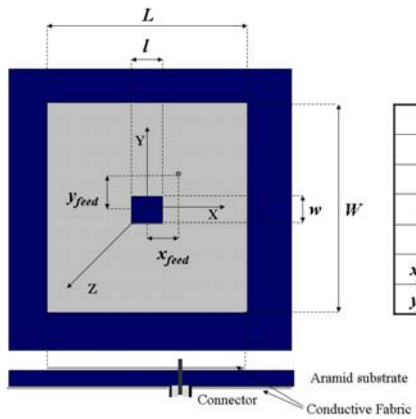
Carla Hertleer and Lieva Van Langenhove are with the Department of Textiles, Ghent University, Technologiepark 907, 9052 Zwijnaarde, Belgium (phone: +32 9 264 54 09; fax: +32 9 264 58 46; e-mail: carla.hertleer@ugent.be and lieva.vanlangenhove@ugent.be)

Hendrik Rogier is with the Information Technology Department, Ghent University, St. Pietersnieuwstraat 41, 9000 Ghent, Belgium (e-mail: hendrik.rogier@intec.ugent.be).

II. Antenna Design and Construction

The basic assumption of our research was a microstrip patch antenna built as a multilayer textile structure. Our goal was to design an antenna for off-body short range communication, known as the Wireless Local Area Network (WLAN) operating in the 2.45 GHz ISM band and based on the Zigbee, Bluetooth, WiFi and Wireless USB protocols. To obtain an antenna with a -10dB return loss in this 2.4 – 2.483 GHz band and a nonlinear polarisation, a single feed rectangular-ring topology [5] was chosen. The geometry of the patch and the location of the feed point were optimised using a 2.5-D field simulator ADS-Momentum® from Agilent Technologies. The dimensions of the antenna are given in Fig. 1 Dimensions of the rectangular-ring textile antenna. Linear polarization is avoided to improve reception in real-life application, where the wearer is mobile and thus continuously changing his orientation with respect to the receiving antenna. In order to achieve circular polarisation, the feed point is placed on a diagonal of the patch. Because of the slightly different values of the length L and the width W of the antenna patch, a broad bandwidth is achieved. As the antenna is meant to operate in the vicinity of the body, it is provided with a ground plane to shield the body from the radiation. However, this ground plane is minimised to 65 x 65 mm.



	(mm)
W	42
L	44
w	7
l	8
x_{feed}	7
y_{feed}	6

Fig. 1 Dimensions of the rectangular-ring textile antenna

Since the antenna was designed for integration into a fire fighter's jacket, the outer shell fabric was chosen as antenna substrate. This is a high performance aramid woven fabric with a thickness of 0.40 mm. However, because we require a bandwidth of over 83.5 MHz, an antenna substrate with a sufficient thickness is needed. Therefore we assembled 4 aramid layers using an adhesive sheet, resulting in an overall thickness of 1.67 mm. This antenna substrate possesses an ε_r of 1.75 and a loss tangent of 0.015. Commercially available electrotextiles with a very high conductivity (surface resisitivity <0.1 Ω/sq) were used for patch and ground plane.

III. Simulation and Measurement Results

First, the antenna was measured in planar state in order to compare the simulated and measured return loss. Second, the return loss of the bent antenna was evaluated. Therefore the antenna was curved over a plastic tube with a diameter of 8 cm, which corresponds with an arm or a shoulder. To perform these measurements, an Agilent 8714ET Network Analyzer was used. Simulation and measurements are compared in Fig. 2 and show first-rate agreement. A robust design is obtained by increasing the bandwidth up to 100 MHz, instead of the required 83.5 MHz in the 2.45 GHz ISM band. This is done because we expect a shift in frequency in real-life application due to manufacturing tolerances and bending of the antenna patch and the presence of the human body. The measured bandwidth of the textile antenna is found to be slightly over 100 MHz, both in planar and in bent state.

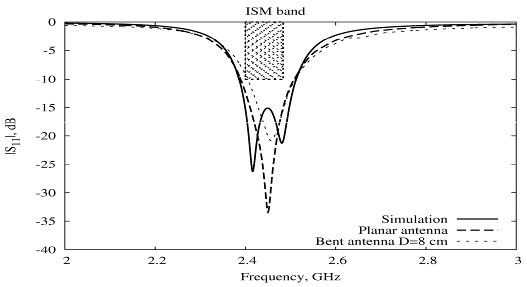


Fig. 2 Measured and simulated return loss

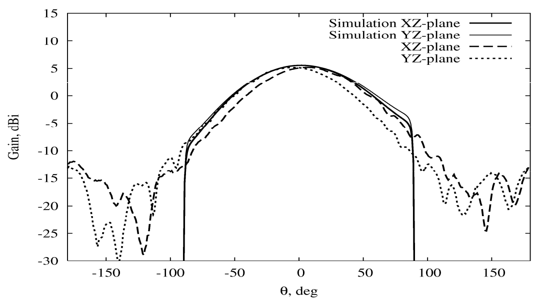


Fig. 3 Simulated and measured gain of the planar antenna at 2.45 GHz

For the transmission measurements, our antenna was combined with a standard gain horn antenna in an anechoic room and an HP 8510 Network Analyzer was used to perform the measurements. From the obtained radiation patterns in XZ and in YZ plane at a frequency of 2.45 GHz, an antenna gain of 5 dBi is found. It is clear from Fig. 3 that a back radiation is present due to the very limited dimensions of the ground plane. However, because flexible electrotextiles are applied, the ground plane can easily be enlarged without obstructing the wearer. Comparison between simulation and measurement reveals also for the transmission characteristics, excellent agreement.

In order to simulate real-life application, **Fig. 4** compares 3-D simulation of the antenna at 2.45 GHz when applied in air and on the human body.

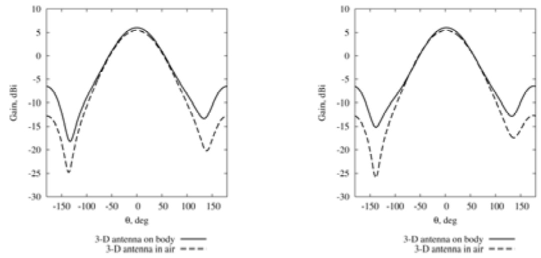


Fig. 4 3-D simulated antenna gain at 2.45 GHz

For this simulation the antenna has a finite ground plane (66 by 63 mm) and the human body is represented by a homogeneous lossy dielectric with an ε_r of 42 and a σ of 0.99 S/m (as proposed by CENELEC) which is modelled at 8 mm below the finite antenna ground plane. This was done using a CST Microwave Studio® 3-D field simulator.

It can be observed that these additional restrictions have only a limited influence on the radiation characteristics of the antenna.

IV. Conclusions

A microstrip patch antenna based on a high performance aramid fabric, to be integrated into a protective fire fighter garment was presented in this paper. The antenna was designed to operate in the 2.45GHz ISM band for off-body communication. Excellent agreement was found between the simulated and measured reflection and transmission characteristics of this textile antenna. Furthermore a rectangular-ring topology guarantees reception of both horizontally and vertically polarised fields.

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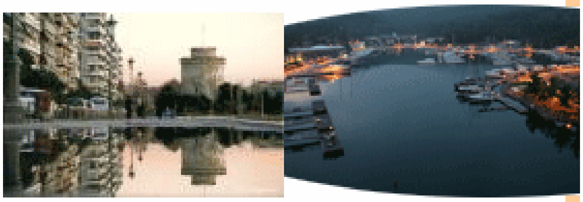

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